Hydrogeology-specific groundwater model boxes could improve low flow modelling by 30%.

Recharge stress leads to different baseflow responses for both pre-drought and drought periods and different flow regimes.

**BACKGROUND**

This study identifies the drought resistance on catchment scale based on recharge stress tests. Pre-drought recharge is systematically decreased and baseflow response is quantified for different drought events and flow regimes.

The best of nine optional model structures is assigned to each catchment to translate recharge into baseflow. This model then performs the stress test.

**BEST MODEL STRUCTURES**

5 of 9 model structures stick out in terms of model performance (details on page 2). We found a strong relationship between hydrogeology and best performing model structures.

**BASEFLOW RECOVERY**

We found that catchments return to the reference baseflow on different timescales, i.e. for flashy regimes after 6-12 months. The variation of return durations between drought events is smaller than the variation of return durations between flow regimes.

Decrease in low flows is slightly higher for flashy flow regimes. With drier pre-conditions (i.e. longer return periods) NQ decreases by several percent.

**CONCLUSION**

We found clear relationships between catchments’ geology and appropriate groundwater model structures.

Classification of catchments into flashy and stable regimes uncover differences in drought resistance and stress test recovery. Higher resistance leads also to longer stress test recovery.

Detailed methods and more results on page 2.
STRESS TESTS

Baseflow stress testing uses historical extreme events and simulates their progress under drier precitions. The catchments’ drought resistance is then assessed by the degree of response on stress testing, e.g. baseflow recovery from stress tests. The last period with median streamflow before major drought events (1991, 2003, 2011, 2015, 2018) is identified as starting point for stress testing. From this point recharge stress tests with durations between 1 and 24 months reduced the pre-drought recharge to quantities with a return period of 50, 100 and 200 years. The calibrated model structures then simulate stress test series (i.e. baseflow) with the decreased recharge input.

CATCHMENTS

54 study catchments located in Southwestern Germany. Catchment areas are 10-250 km², mean area is 100km². Catchments are all rainfall-dominated and have variations in precipitation, evapotranspiration, geology, land use etc. Urban areas are negligible. Flow regimes (flashy, moderate, and stable) are classified with low flow stability index $Q_{50:10}^2$.

DATA

We use data from the last 35 years (1984-2018) including five major drought events in Germany (1991, 2003, 2011, 2015, 2018). Observed streamflow and recharge series are converted to pentads (five day blocks) to ensure that recharge dynamic is not overestimated and to improve computation time.

MODEL STRUCTURES: DETAILS (6 of 9 boxes)

For each catchment the performance of the eight model structures is compared against a simple linear model (L1). This benchmark a general ranking of the different structures and a catchment-specific ranking is possible. With the benchmark variations in model efficiency across catchments are adjusted.

PA2 and LAY are the best performing model structures (77%). Some catchments (23%) have MAT, LBY1 and LL1 as best structures. All structures are superior to a simple linear storage box (L1) which is still often implemented in hydrological models to simulate low flow.

LINK BETWEEN HYDROGEOLOGY AND MODEL STRUCTURE

Best model structures are linked to catchments’ hydrogeology, e.g. LBY1 is often best model for mainly porous aquifers, L1 for karstic etc., LAY is more versatile structure, PA2 is compared to LAY better if hydrogeology is more homogenous.

BENCHMARK

For each catchment the performance of the eight model structures is compared against a simple linear model (L1). With this benchmark a general ranking of the different structures and a catchment-specific ranking is possible. With the benchmark variations in model efficiency across catchments are adjusted.

BASEFLOW = DELAYED FLOW

Baseflow is separated from observed streamflow series with the DFI method (Delayed Flow Index, Stoelzle et al., 2020). The DFI method is an advancement of two-compartment basin separation to quantify multiple delayed streamflow components. For each catchment four components with different delays were identified. The fastest (short-delay) component was removed from observed streamflow to derive a continuous basin series.

CALIBRATION and OF

Calibration of the two-parameters box models is done with evolutionary global optimization via the Differential Evolution algorithm (R package DOptim). The objective function (OF) minimizes a equally-weighted combination of MARE (Mean Absolute Relative Error, %) and logKGE (-). Both parts are calculated split-wise for each year. For MARE calculation more weights are given to periods with low flows and periods with higher proportion of baseflow. Model warmup are the first 5 data years, calibration period is between 20-26 years, validation period is 4 years (the years 1995 - 1998 included for all catchments dry, wet and average years).

FURTHER READING

